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THE DEVELOPMENT OF A BETTER RESTRAINT DEVICE  
FOR INFANTS USED ON BOARD COMMERCIAL  
TRANSPORT AIRCRAFT

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Pamplona, 27 de Julio de 2011

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# Author's Declaration

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# ABSTRACT

This project arises from the fact that nowadays infants who travel by plane do it on the lap of the adults using a two-point security belt that turns out to be quite inappropriate for them.

There exist studies that demonstrate that this type of belt can cause serious abdominal and column injuries being able to cause the death of the passenger in an extreme situation. In addition this restraint system does not protect the head of the infant for what there is also risk of suffering neck injuries.

For these reasons this project has been realized in order to increase the safety of the infants designing a new restraint device that increases the safety of infants who travel on board commercial transport aircraft. For the design of the device there has been used the software SolidWorks. This software is a very used tool nowadays in the design by computer.

With the design of the device, which will be explained later in this document, and after the analyses realized on the same one to verify its efficiency, it is possible to conclude that the aim of increasing the security of the infants who travel by plane has been obtained.

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# 1.INTRODUCTION

The aim of this project is to improve the security of infants who travel onboard commercial transport aircraft by developing a restraint device better than the one that actually exists. Infants are defined as persons who are less than two years of age.

This project arises from the fact that nowadays infants travel on the lap of an adult with the only restraint of a belt that is hooked to the adult's one. This belt, which is shown in Figure 1, is a two-point security belt which seems quite inappropriate for an infant in the event of turbulence or an emergency landing. Infants are fragile persons which can suffer serious injuries with this type of safety belt so for these reasons, it is necessary to develop a new device that increases the safety of infants traveling by plane.

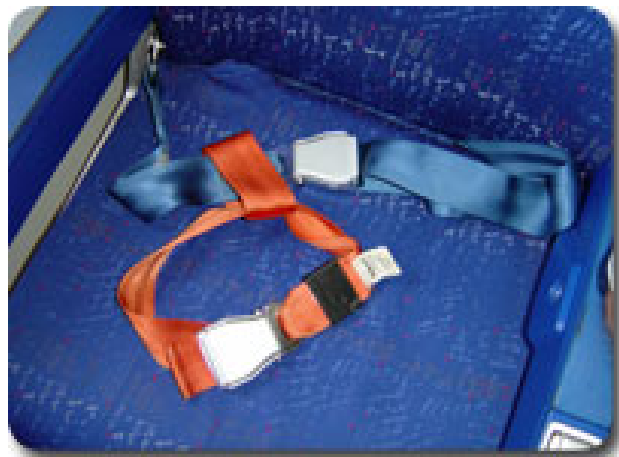


Figure 1.1

*Current safety device for infants*

Through the development of this new restraint device, safety of infants will be increased and damage or injuries that can be suffered with the current security system will be prevented.

The first step to realize the project will be to seek information on existing security measures, both the two-point belt used by the airlines and other devices that also can be used onboard commercial transport aircraft instead of this security belt, for

example the CRDs. In addition, this search will penetrate into the history of the two-point belts and into the problems and injuries that can cause in an emergency.

Besides this information, it is also needed information about aviation legislation and security policies of the airlines since the new device has to adapt to the rules of these companies and agencies. Agencies like the Federal Aviation Administration (FAA) in USA, the Civil Aviation Authority (CAA) in UK or the European Aviation Safety Agency (EASA) in all Europe are the managers of formulating the safety regulations that all the airlines must fulfill for what it is indispensable that the new device adapts to these rules.

Once enough information has been collected, the next step in the project would be the design of possible solutions and choose the one that best suits the needs previously studied.

After choosing the most appropriate model, the next stage would be to choose the materials and components of the restraint device to analyze the efforts that are suffered in turbulence or emergency landings. These materials must be light and resistant at the same time. In addition it would be suitable that the materials that form the cot were soft to the tact to increase to the maximum the comfort of the infant who uses the device.

Finally, with the results of the analysis, the final design of the restraint device will be made.

## 2. AIMS OF THE PROJECT

The principal aim of this project, as it has been said before, is to improve the security of infants who travel onboard commercial aircraft.

The current systems of safety that are in use for infants in aircraft turn out to be inappropriate and insufficient even more if they are compared with those who are in use in others means of transport since can be cars. In this case, it is used a special chair with a four or five-point security belt.

Parents who travel with their children in a plane have the option to book another seat for the infant and use a special chair called CRD (child restraint device), which is almost the same as in cars, or they can take their child in their lap. Thus they only have to pay a small percentage of the ticket or nothing more than the rates or the insurance of the trip. By this project, what is claimed to achieve is that infants who travel on the lap of an adult, without paying an extra ticket, will travel with the same levels of safety than the ones who travel on an approved CRD.



Figure 2.1

*Types of Child Restraint Devices*

To sum up, with this project the safety of the infants who travel by plane will increase without concerning the price that parents have to pay.

# 3. REVIEW OF LITERATURE

## 3.1. INTRODUCTION

In this section it is exposed all the necessary information that has been compiled for the accomplishment of the safety device. This information includes important points such as for example information about the current security measures, all the regulations that must be expired by the device or types of air emergencies. Besides this information, it is also included information about materials and their regulations to form the new restraint device.

## 3.2. CURRENT SECURITY MEASURES. THE TWO-POINT SECURITY BELT

A safety belt is a harness designed to hold an occupant of a vehicle or aircraft in his seat. They began to be in use in aircraft in the decade of 1930 and his use in cars is nowadays obligatory. The safety belt is considered to be the most effective system of passive safety never invented, included the airbag or any technical advance of nowadays.

The aim of the safety belts is to minimize the injuries in a collision, preventing that the passenger strikes himself with the hard elements of the interior or against the persons in the previous row of seats.

The two-point security belt is the one that is placed on the hips of the passenger. It is used principally in aircraft and buses. It consists only of a low band and is five times less sure than the three-point belt. It has been criticized for causing the separation of the lumbar thorn, causing sometimes paralysis known as “syndrome of the safety belt”.



Figure 3.1

*A two-point security belt*

This syndrome causes an acute spinal cord injury due to the incorrect use of the two-point belt. This syndrome associates vertebral and spinal cord injuries, intra-abdominal, cutaneous and muscle skeletal lesions and the main cause of these injuries is the bad use of this seat belt. The belt must be placed ahead of the bones that stand out in the hips. This is to hold the body against a hard bone and not against the soft abdomen.

### 3.3. AVIATION REGULATION

In this part it is going to be developed the regulations that are necessary to bear in mind in the design of the new restraint device. It will be divided in two parts, one referred to the aviation safety agencies and the other referred to the airlines.

#### **3.3.1. Aviation safety agencies**

The functions of these agencies are to unify the common standards of airworthiness as well as to guard over the environmental protection in the civil aviation. In addition, they take charge developing the common laws for the civil aviation, assuring the fulfillment of them. Some of the most important agencies in the world are the European Aviation Safety Agency (EASA) in Europe, the Federal Aviation Agency

(FAA) which belongs to USA, the Civil Aviation Authority (CAA) in UK, the Civil Aviation Safety Authority (CASA) in Australia or the Agencia Estatal de Seguridad Aérea (AESA) in Spain.

- The European Aviation Safety Agency (EASA) is an agency of the European Community, which has been given specific regulatory tasks in the field of aviation safety. Its establishment is key to the implementation of the European Union's strategy to maintain and improve the level of aviation safety in Europe and beyond.

As far as its regulation is concerned, the EASA requires a child restraint device acceptable to the authority for each infant. It recognizes child seats approved for use in automobiles or aircraft, called child restraint devices (CRDs), or a supplementary loop belt restraining the infant to the safety belt of the adult passenger holding the child on the lap. This belt is provided by the airlines but the CRD must be provided by the parents and it must be fixed appropriately to the seat of the plane.

- The Federal Aviation Administration (FAA) is the governmental entity responsible of the regulation of all the aspects of the civil aviation in the United States.

The FAA does not require the use of CRDs on commercial airplanes because a mandate would require parents to purchase an extra airline ticket for their child, forcing some families who can't afford the extra ticket to drive, a statistically more dangerous way to travel. However, the FAA strongly recommends the use of CRDs or an alternative FAA approved device because infants traveling on the adult's lap is not the safest way for infants to travel with the current existing security measures.

- The Civil Aviation Authority (CAA) is the UK's independent specialist aviation regulator. Its activities include economic regulation, airspace policy, safety regulation and consumer protection.

CAA regulations require that all passengers be secured by means of the seat belt provided. In the case of infants this must be achieved by the use of a child restraint device (CRD) acceptable to the airline and the CAA. Examples of CRDs include:

- A supplementary loop belt provided by the airline to secure the infant on an adult's lap.
- A car type seat approved for use in motor vehicles, provided by the passenger, or a CRD qualified for use in an aircraft provided by the airline.

Forward-facing CRDs may be installed on both forward and rearward-facing passenger seats but only when fitted in the same direction as the passenger seat on which it is positioned. CRDs shall only be installed on a suitable aircraft seat with the type of connecting device for which they are approved or qualified.

A CRD is considered to be acceptable if it is a 'supplementary loop belt' manufactured with the same techniques and the same materials of the approved safety belts, or a device which can be installed properly on the respective airline seat.

- The Civil Aviation Safety Agency (CASA) is the Australian national aviation authority, the government statutory authority responsible for the regulation of civil aviation.

CASA regulations say that an infant carried in the arms of an adult passenger (lap held) must be restrained, but the adult seat belt must not be fastened around both adult and infant. A device known as a supplementary loop belt provides an additional seat belt with stitched loops through which the adult belt is passed. The adult belt is fastened around the adult and the additional belt is then separately fastened around the infant. This is the only known device which provides an acceptable restraint for a lap held infant.

Apart from that, CASA adds that the supplementary belt will provide some restraint to an infant during turbulence or mild longitudinal emergency loading such as a rejected take off. However, this belt does not provide an equivalent level of protection to a lap belt restraint for a separately seated adult. The supplementary belt is even less effective for a new-born infant as their skeletal structure would be unable to cope with any significant load from the 5 cm wide webbing. For an equivalent level of protection, all infants should be seated in an individual infant restraint device in a separate passenger seat.

As a summary, all the safety agencies accept the supplementary belt as a safety measure for infants but they all admit that this belt turns out to be inadequate and does not offer the necessary levels of safety. For these reasons it is necessary the development of a new device that improves the current one.

### **3.3.2. Airlines**

Apart from the safety agencies, airlines have their own security policies but always inside the established for the agencies. In this paragraph the security policies of some of the most important airlines in the world have been investigated since they are the ones that transport the majority of the passengers who travel by plane. These airlines are Air Europe, Air France, Alitalia, American Airlines, British Airways, Emirates, Iberia, Lufthansa and Ryanair.

Like a summary is possible to say that when someone travels by plane with an infant there are two different options. The first one is that the infant travels on the lap of an adult using an extension of the seat belt of the adult. This supplementary loop belt must be manufactured with the same techniques and the same materials of the approved safety belts. The other option is that, if there are available seats or if parents book one in advance, the infant rides in a CRD approved by the airline and the safety agencies. This child restraint device must be fixed to the seat of the plane. This chair can be provided by the airline or by the parents.



## 3.4. TURBULENCE AND EMERGENCIES

### **3.4.1. Turbulence**

Turbulence is defined as a state of a fluid in which the speeds of the particles show irregular and random fluctuations. Referred to aeronautics, it can be defined as the way change and/or speed of the wind in extremely short sections of flight. These irregular flows produce on the aircraft sudden changes in the path and losses in the sustentation. It may occur when the sky appears to be clear and can happen unexpectedly. It can be created by any number of different conditions, including atmospheric pressures, jet streams, mountain waves, cold or warm fronts or thunderstorms.

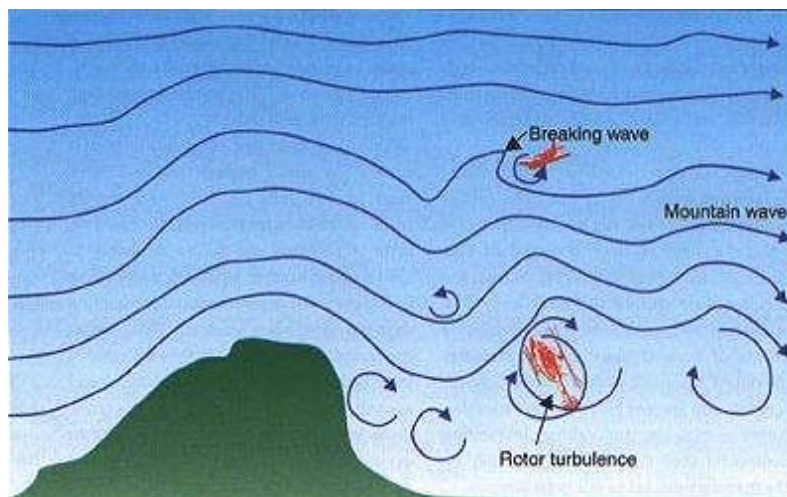


Figure 3.2

*Formation of turbulence*

Turbulences are associated with different types of cloudiness and can be qualified in the following way:

- Light turbulence: briefly causes slight, erratic changes in altitude and/or attitude.

- Moderate turbulence: similar to light turbulence, but greater intensity. Changes in altitude/attitude occur. Aircraft remains in control at all times. Variations in indicated air speed.
- Severe turbulence: large, abrupt changes in altitude/attitude. Large variation in indicated airspeed. Aircraft may be temporarily out of control.
- Extreme turbulence: aircraft is violently tossed about and is impossible to control. May cause structural damage.

The reactions inside aircraft vary from occupants feeling slight strain against their seat belts and unsecured items being slightly displaced, through to occupants being forced violently against seat-belts, and unsecured items being tossed about.

There are several notable problems with clear air turbulence:

- It cannot always be foreseen so there is no warning.
- It is usually felt at its mildest in the flight deck and is generally more severe in the aft section.
- It can occur when no clouds are visible.
- Aircraft radars can't detect it.
- It is common at high altitudes, where cruising airline suddenly enter turbulent areas.

Turbulence is the first reason of hurts and injuries in passengers and crew in accidents that do not have a fatal result. There are countless reports of occupants who were seriously injured while moving about the passenger cabin when clear air turbulence is encountered. According to the FAA (Federal Aviation Administration), in the last 15 years there have happened 2 deaths, 63 gravity injured men and 863 injuries for accidents related to turbulences, most of these people were not wearing the seat belt.

### 3.4.2. In an emergency

Over 70% of airline accidents are survivable. Brace or crash position is an instruction that can be given to prepare for a crash. There are many different ways to adopt the brace position, with many countries adopting their own version based on research performed by their own aviation authority. It has been proved that passengers who assume the brace position sustain substantially less serious injuries than other passengers.

Phrases such as 'brace', 'head down, stay down'; and 'grab your ankles' are commonly used to tell passengers to assume a protective position. This position is shown on the safety card, located in the aircraft seat pocket in front of the passenger. The seat allocation will determine the safest crash position to assume.

If the seatback or bulkhead in front of the passenger is beyond reach:

- Upper body bent forward as far as possible with the chest close to the thighs and knees
- Head down as low as possible
- Arms around or behind legs, tucked in against your body
- Lower legs angled behind the knee joints
- Feet placed flat on the floor

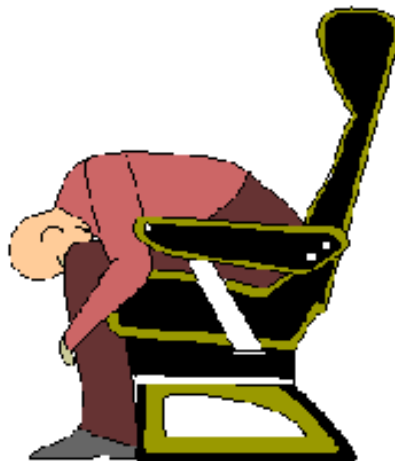


Figure 3.3

*Brace position*

If the seatback or bulkhead in front of the passenger is within reach:

- Upper body bent forward as far as possible
- Head touching the seat back or bulkhead in front
- Hands placed one on top of the other and on top of the head. Fingers should not be interlocked
- Forearms tucked in against each side of the face
- Lower legs angled behind the knee joints
- Feet placed flat on the floor



Figure 3.4

*Another type of brace position*

An unrestrained infant cannot be held safely in an accident. As far as infants are concerned, the best position is cradling the child with one arm and using this to also protect the child's head.

### 3.5. EMERGENCY PROTOCOLS

A protocol for emergency evacuation of an aircraft consists of a series of regulations to facilitate the rapid departure of the plane passengers after an accident.

In the event of an evacuation, the best preparation is to be aware of your closest exits, be ready to follow flight and cabin crew instructions, wear slide friendly clothes and shoes, and leave all your possessions behind. If the emergency oxygen masks drop down, put your own mask on first. This will decrease the risk of you passing out before being able to help your children or other passengers.

When some damage arises in the aircraft the first thing that will happen is that the pilot will activate the button of evacuation, where the lights of emergency and the alarm will ignite to proceed to leave the plane. Forthwith, the crew will take charge opening the emergency doors or looking for the best way of retiring to the aircraft. It is clear that in agreement to the location of every passenger they will have to evacuate the plane across the most nearby door of emergency.

If the plane has fallen to the sea, adults must never inflate their life jackets in the interior of the plane. This does not happen with infants since, unlike with adults, they must inflate it inside the cockpit of the aircraft. This information must to bear in mind in the moment of designing the new restraint device.



Figure 3.5

*Life jacket used on aircraft*

### 3.6. CRASH TESTS

To verify the efficiency of different restraint devices some standard tests are realized according to the specific regulation.

The most famous tests are realized by an organization called Euro NCAP. Euro NCAP is a program created in 1996 by the interest of various organizations and countries for the development of crash tests with the purpose of increase the security of the passengers of cars. Over the time these tests were increasing their demand and also analyzed the different types of restraint devices used in cars or aircraft.



Figure 3.6

#### *Crash test for a three-point security belt*

There are two different types of crash tests. The first one is the frontal impact. This test is performed at a speed of 64 km/h. A car hits a deformable barrier of 54 centimetres wide and one metre long that represents the collision with another car with the same weight and size.

The other type of test is a side impact test. In this case the vehicle is beaten by a deformable aluminium block at a speed of 50 km/h.

Through the use of some dolls, called dummies, it can be seen the efforts that are suffered in an accident and the effectiveness of the safety devices.

### 3.7. FIREPROOF MATERIALS

As far as the design of the device and its materials is concerned, these materials must be fireproof materials in agreement with the regulations.

A fireproof material is defined to that one that possesses or provides relatively low indexes of inflammability and spread. They are fabrics that are combined by natural threads to which there is applied a retardant. In some cases the fireproof fabric is a cellulose fabric that it remains difficultly inflammable thanks to the incorporation in its mass of a fireproof agent exempt from halogen. The fabrics do not form drops of merger to the heat of the flames and show excellent physiological properties for its high capacity of absorption of dampness.

The natural fabrics of animal origin such as wool present a high temperature of ignition (500-600°C), superior to those of vegetable origin (cotton, linen) near to 400°C, with the additional advantage of which they carbonize but not fused.

The adoption of the synthetic fabrics (acrylic, polyester, nylon, rayon, polyethylene, polypropylene, etc.) for his big mechanical advantages - between others-, it does not improve the conditions in the fires since though they have a point of ignition of 500-600°C, they burn with facility and intensity, they fuse, leak and generate gases and more toxic smokes. For it they are in the habit of combining with natural fabrics that improve his properties opposite to the fire or even with fabrics of inorganic not combustible materials.

The fireproof treatment is achieved by means of someone of the following methods:

- Chemical reaction
- Impregnation (for saturation, for absorption, and to pressure)
- Covering

In case of the chemical reaction, the material warms up and combines chemically with the fireproof substance. It is a process limited to the industrial manufacture, used in plastic and textile but impossible to apply when the material or product is already acquired and installed.

The impregnation consists of dissolving or dispersing a fireproof material in a solvent, generally water. Then it soaks or saturates the element to treating, for aspersion or dip. If it is applied flame retardant salts, the crystals stay between the fabrics of the textile. The impregnation by pressure turns out to be more effective and lasting.

The retardant coverings of flame can be applied during the manufacture of the product, since for example in not absorbent materials of the construction, decorative pieces, and sometimes, on textiles.

<b>Flame retardant chemicals</b>	
<b>Fiber</b>	<b>Flame retardant</b>
Cotton	Phosphonium salt of tetrakis (hydroxymethyl) insolubilized with ammonia gas
Cotton. Rayon (non-woven and non-durable finishes)	Diammonium phosphate / ammonium sulfate / boron compounds
Rayon (modified fibre)	Phosphazene hexapropoxi
Polyester (modified fibre)	Oligomeric phosphate
Polyester, acetate, nylon	Decabromo-diphenyl ether (DBDFE) and antimony oxide
Nylon	Thiourea / titanium and zirconium compounds / dibromide-terephthalic acid
Modacrylics (modified fibres)	Vinyl chloride, vinildeno chloride, vinyl bromide as a precursor

Table 3.1

*Chemicals used as flame retardants according to the type of fabric*



## 4. DESIGN PROCESS

### 4.1. INTRODUCTION

After studying all the previous information, in this section it is going to be explained the development of the design of the restraint device. With the new device safety of infants will increase and for that several ideas have been developed up to coming to the final design of it.

Before beginning with the design of the device it is necessary to bear in mind some important information since it is the height and weight of infants according to their age. These data are shown in the next table.

BOYS			GIRLS		
AGE	WEIGHT	HEIGHT	AGE	WEIGHT	HEIGHT
Newborn	3.4 Kg	50.3 cm	Newborn	3.4 Kg	50.3 cm
3 months	6.2 Kg	60 cm	3 months	5.6 Kg	59 cm
6 months	8 Kg	67 cm	6 months	7.3 Kg	65 cm
9 months	9.2 Kg	72 cm	9 months	8.6 Kg	70 cm
12 months	10.2 Kg	76 cm	12 months	9.5 Kg	74 cm
15 months	11.1 Kg	79 cm	15 months	11 Kg	77 cm
18 months	11.8 Kg	82.5 cm	18 months	11.7 Kg	80.5 cm
2 years	12.9 Kg	88 cm	2 years	12.4 Kg	86 cm

Table 4.1

*Weights and heights of infants*

This information will be used to bring an idea of the dimensions of the restraint device.

## 4.2. DESIGN DEVELOPMENT

In the stage of the design of the restraint device it was to bear in mind that infants travel on the lap of the adult so that the device did not have to be very big or weighed to not to alter the comfort of the adult but, at the same time, it had to be safe for the infant.

The first sketch of the device consists of a pair of straps for which there interfere the arms and other one to join both that serves to hold the chest of the infant. These straps would be made by the same material that the safety belt of the adult. The central hooking would be similar to the one that is used, for example, in the helmets of the motorcycles and in the low part of the same ones there would be a metallic hooking to hold the device to the belt of the adult. These metallic hooking would be jagged in their interior to provide a good fixation of the device to the belt of the infant. With this design the infant travels with a four-point security belt instead of the two-point security belt which is used nowadays.

An image of the design is shown in the next picture:

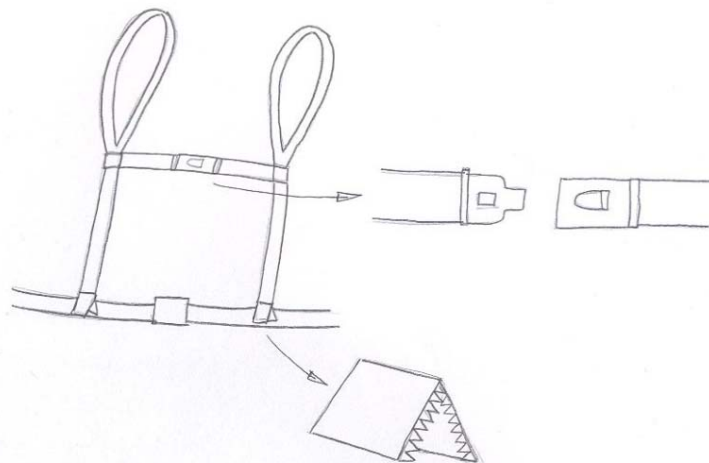


Figure 4.1

*First sketch of the device*

This model was rejected because it does not hold adequately the head of the infant for what he might suffer injuries in the neck or in the spinal cord in case of an accident.

In order to solve these problems it was designed another device. This second sketch is similar to a cot in which the infant travels lied down in its interior. With this it is achieved that the infant travels more protected and the risk of suffering neck injuries are reduced since traveling inside the cot limits the range of motion of the infant.

This cot is hooked to the adult's belt by two different forms. In the back part of the cot there are two loops for which passes the adult's belt and in the wings of the cot there are a couple of straps that stick to the adult belt with a metallic hooking to improve the restraint. As in the first case these metallic hookings are jagged in their interior and the straps are made of the same material as the current safety belt too. This design is more suitable than the previous one because the infant travels more fastened.

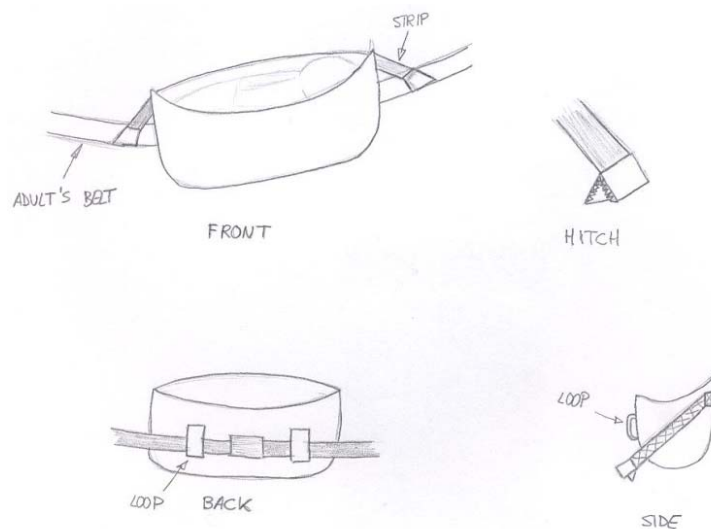


Figure 4.2

*Second sketch of the device*

Based on this design, several improvements were added to the device. It is possible to see that in case of turbulences or an emergency landing the infant can go out of the cot and be struck against the cockpit of the plane so for this reason it was

necessary to add an interior hooking to immobilize the infant to prevent that, as it is shown in the next picture.

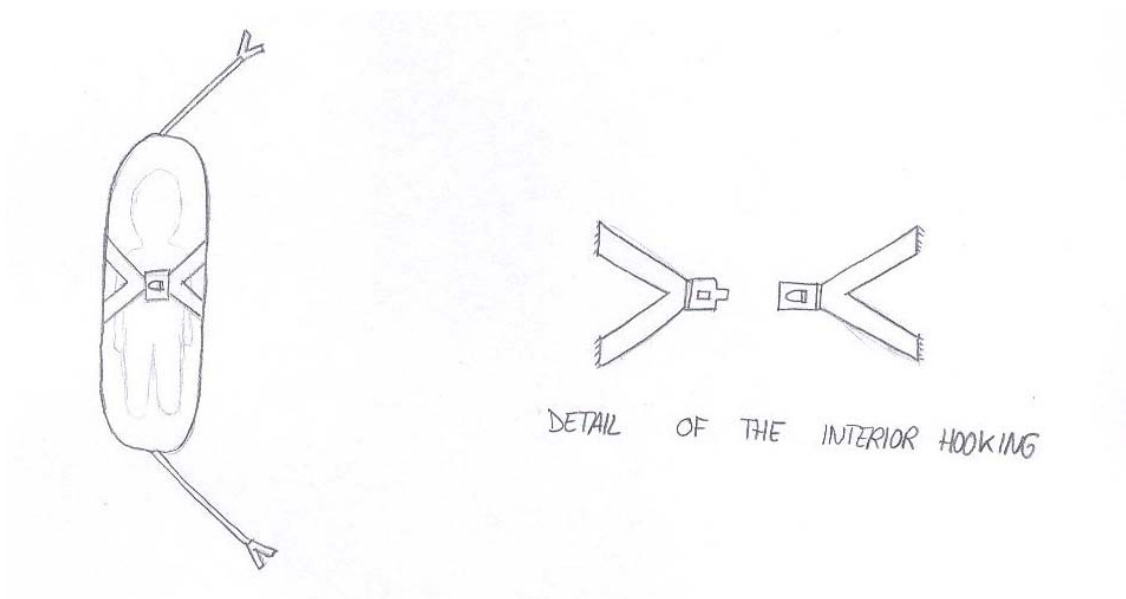


Figure 4.3

*Improvements on the device*

The union of these straps is similar to the one used in helmets of motorbikes. By this union the infant could not open it since it is placed in the exterior part and in addition, it is necessary some force to open it.

To facilitate the manufacture of the restraint device several changes were realized in the design. The first one, and more important, was a change in the form of the cot. Instead of having the base rounded it was decided that the best option was to change the form of the cot and to a flat base with form of ellipse.

Apart of this and thinking about the possible emergencies that can happen in a flight, a pair of handles was added to the cot in order that the device could be transported easily in case of an evacuation of the plane.

Another modification that was realized on the cot was to add a material of landfill between the walls and in the base of the cot. Hereby the infant can travel more comfortably inside the same one increasing his comfort.

Finally in the back part of the cot a material of reinforcement was added since this zone must support all the efforts that appear in turbulences or an emergency landing by means of the efforts transmitted for the belt of the adult across the back loops of it.

All these changes in the design of the restraint device can be seen in the following images:

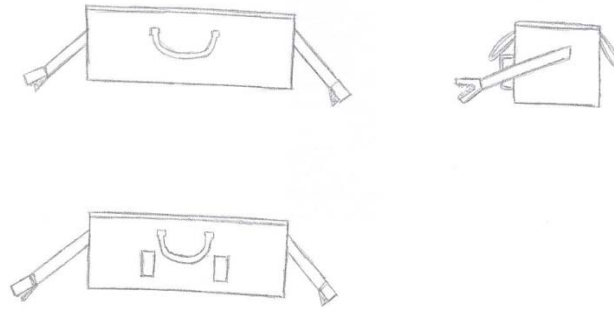


Figure 4.4  
*Different sights of the design*

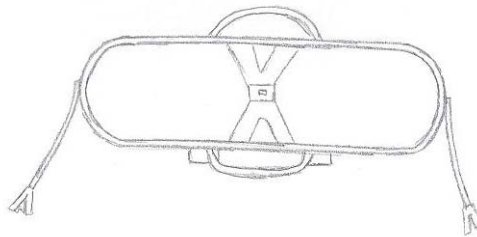


Figure 4.5  
*Top sight of the device*

After all these improvements in the design of the device we have the final design of it.

The new restraint device designed consists of a quilted cot with a flat base with a form of ellipse on which the baby travels lied down. The walls of the cot are also quilted and in the back part of it there is a reinforcement material to support the efforts that happen during the emergencies. In the back part of the cot there are two loops across which the belt of the adult passes to hold the cradle. In the wings there are two straps with a metallic hooking in their end that are jagged in its interior to fix the cot to

the belt of the adult and to prevent the device from moving. Finally inside the cot there is a hooking to hold the baby and to prevent it from going out of it.

The final design remains reflected in the following sketch:

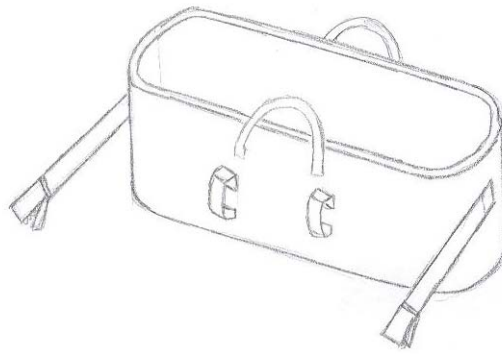


Figure 4.6  
*Drawing of the final design*

In the following section of the report it is going to be explained more detailed this final design of the restraint device explaining all its components, the materials and more important characteristics of the same ones. In addition it will be explained how to manufacture it using a sewing machine.

## 5. RESULTS AND DISCUSSION

### 5.1. INTRODUCTION

In this section it is going to be explained the final design of the restraint device more detailed. By means of the design of the same one with the software SolidWorks it will be able to appreciate all the details of the device. In addition it is going to be shown the different parts of the device and some of the most important characteristics of it as its dimensions or the material that compose all these parts.

Finally, and thinking about the manufacture of this device, it will be marked the steps realized for the manufacturing of the same one to explain clearly its manufacture.

As soon as the final design was chosen the device was designed by means of the software called SolidWorks. SolidWorks is a program of computer-aided design for shaped mechanic. The program allows to design pieces and sets and to extract planes of them and another type of information necessary for the manufacture. It is a program that works with base in the new technologies of shaped with systems CAD.

It is important to comment that the device designed is thought for infants of ages between 0 and 1 years of age.

## 5.2. FINAL DESIGN

The final design of the device is observed in the following figure:



Figure 5.1

*Final design*

This new restraint device consists principally of a cot in which the infant travels lied down in its interior. The cot has a flat base with form of ellipse about which the walls of the same one are placed. Inside the walls and the base there is a material of landfill to increase the comfort of the cot. In the back part of it and between the material of landfill there is a material of reinforcement in this zone in order that the device bears the possible efforts that are suffered in some emergencies. Finally in the top edge of the cot there is an elastic wire to provide to the walls of the cot the suitable form.

In the back part of the cot there are two loops across which the belt of the adult passes. Hereby the device remains fixed and it is prevented from falling to the floor.

It is known that when an air emergency happens as for example an emergency landing, it exists some protocols of evacuation of the plane so that it is necessary that the device has something in order that it could be transported easily. To solve this problem a pair of handles has been added in the wings of the cradle so that the transport



of the device should be possible rapidly and without having to extract the baby of the interior of the cot.

To increase the safety of the device and to provide a complete fixation of the device to the belt of the adult, in the wings of the cot two straps have been added in whose ends there are two metallic hookings. These hookings are jagged in their interior. Hereby it is assured the complete fixation of the device to the belt of the adult preventing the cot from not to move.

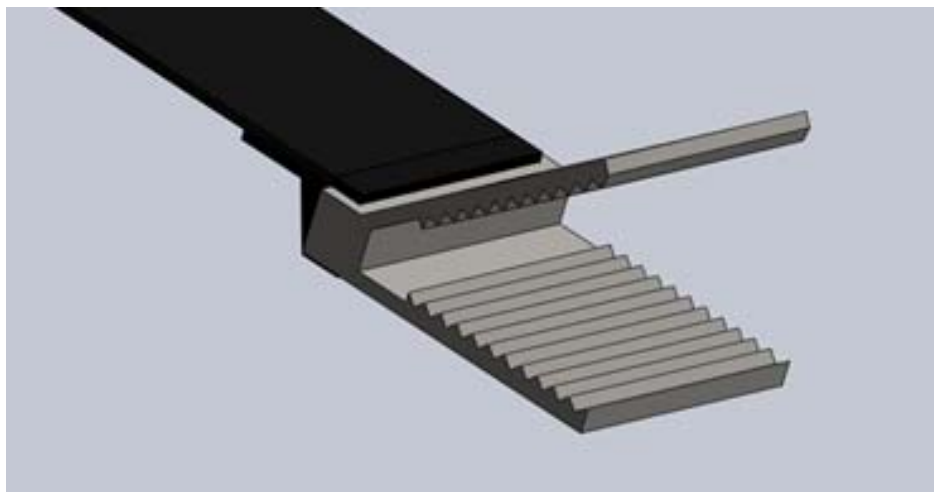


Figure 5.2

*Detail of the jagged hooking*

All of this would be useless if the device has not got anything to protect the baby inside the cot and to prevent him from falling out of it. To solve this problem inside the cot there is a hooking that provides restraint to the infant. It is possible to modify the length of this hooking so that every infant can travel completely subject of agreement to his size.

This is a general description of the final design of the restraint device. From now it is going to be explained more detailed the parts that compose it.

### 5.2.1. The cot

The cot is the principal and more important part of the device since it is in it where the infant travels.

The base of the cot has the form of an ellipse and its dimensions are 75 centimetres long and 30 centimetres width as it is shown in the next picture:

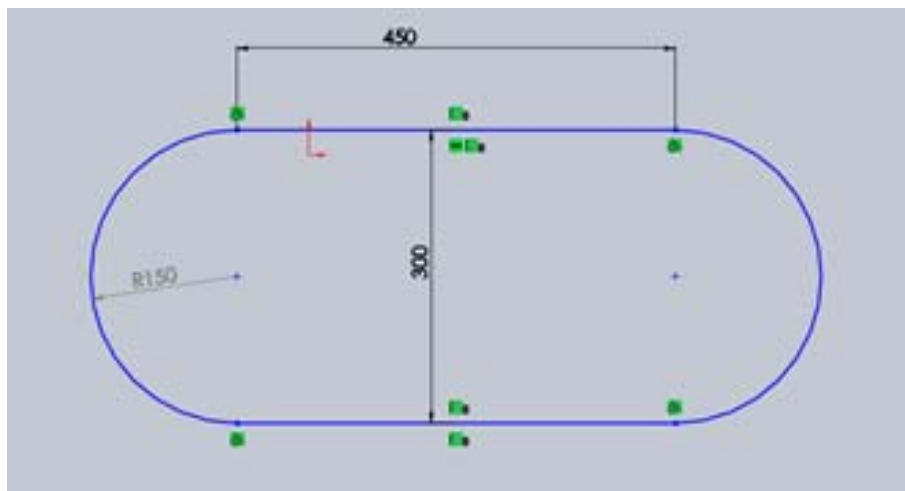


Figure 5.3

*Dimensions of the base of the cot*

The height of the walls is 30 centimetres. With these dimensions the infant can travel comfortably in the interior of the cot and without risks of being able to go out of it. The cot would have the following form:

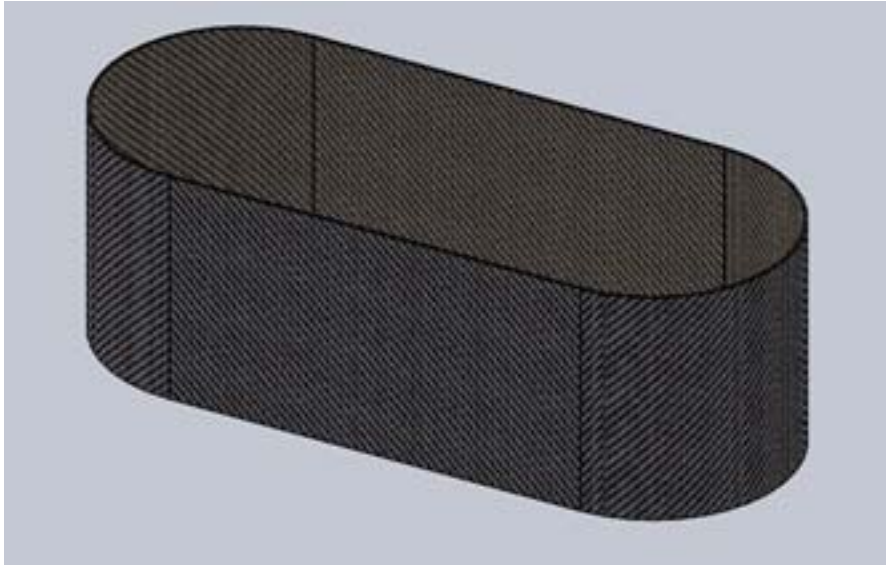


Figure 5.4

*The cot*

The material chosen for the cot is polyester and has the following characteristics:

- Material: 100% polyester
- Composition: 100% IRF polyester fireproof knitted fabric
- Feature: Flame retardant
- Weight:  $210 \text{ g/m}^2$
- Characteristics: Fireproof, durable against norm washing, non-poisonous, smell freely, safe to human body, soft and comfortable

Since it is possible to observe this material is a fireproof material expiring with the regulation marked in reference to the materials used in the components of aircraft. In addition this material expires with the certifications in the United Kingdom as for example the standards BS5815-3, BS5852 or BS5866. These procedures refer to the employment of fireproof fabrics in public places and guarantee that the above mentioned fabrics are resistant to the fire since they must pass some normalized tests to guarantee their resistance.

### 5.2.2. Back loops

As it was said before the cot has several parts. One of them is the two back loops placed in it. The function of these ones is to hold the cot passing the belt of the adult across them.



Figure 5.5

#### *Back loops*

These loops are two straps of 17 centimetres of length and 5 centimetres of width done with the same material that the rest of the cradle, 100% polyester fireproof knitted fabric.

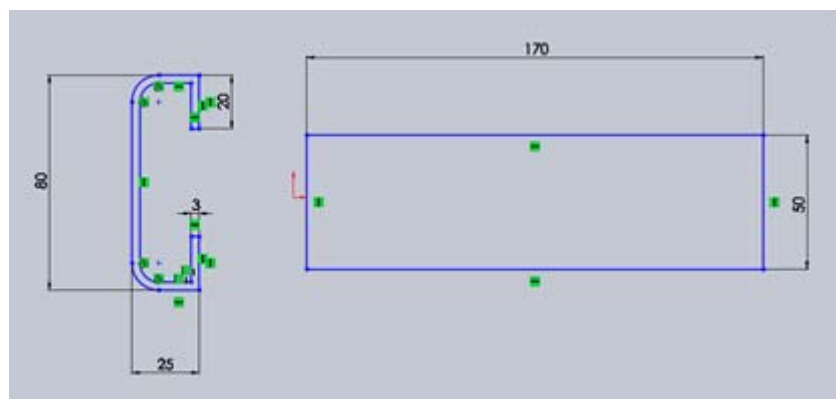


Figure 5.6

#### *Layout of the loops*

The loops are sewed in the back part of the cot and the final result is the one that it appreciates in the figure 5.5. By this form it is obtained a simple and effective fixation of the device to the belt of the adult.

### 5.2.3. Handles

Since it has been said before, the cot has a pair of handles to facilitate its transport in case of an emergency. As the back loops, the handles are also made of 100% polyester fireproof knitted fabric.

The handles also are sewed to the rest of the cradle and consist of a strip of 44 centimetres of length and 8 centimetres of width. After sewing them, the handles have the form of a sufficiently big semi circumference to be able to seize the cot without problems to carry it.



Figure 5.7

*Handles of the cot*

#### **5.2.4. Filling material**

Between the walls and in the base of the cot there is a filling of polyester, the same type of material that is used for refilling the pillows for example, to make the cot more comfortable to the infant.

By means of a cap of landfill of 4 centimetres approximately it is achieved that the cot is more comfortable for the baby and simultaneously it is provided certain protection since with the filling material it is absorbed the small movements or blows that could exist during the flight as for example in the landing.

#### **5.2.5. Reinforcement material**

In the back part of the cot there is a reinforcement material in its interior since it is a zone that must resist the efforts transmitted across the loops when turbulence or an emergency landing happens.

This material could be plastic if it is enough resistant to support most of the efforts that are suffered in emergencies. With this material it is prevented from perforate the fabric of the cot and damage both the adult and the baby.

#### **5.2.6. Elastic wire**

As the walls of the cot do not have the sufficient consistency to support the form of the base it is necessary to add an elastic wire in the top edge. This wire is placed inside the exterior cap of the cot and subject by means of a double in the fabric towards the interior as it is shown in the next picture.



Figure 5.8

*Elastic wire*

The length of the wire is 185 centimetres, the same as the perimeter of the base of the cot.

### **5.2.7. Lateral straps**

In the wings of the cot there are two straps. The material used in these straps is a synthetic fiber as in the current safety belts used in all the cars. This material has some characteristics: Its minimal width must be 50 millimetres and the resistance to the traction of the straps must be equal or superior to 1500 kilograms.

In this case the measures of the straps are 5 centimetres width and 35 centimetres long and they are sewed to the wings of the cot.

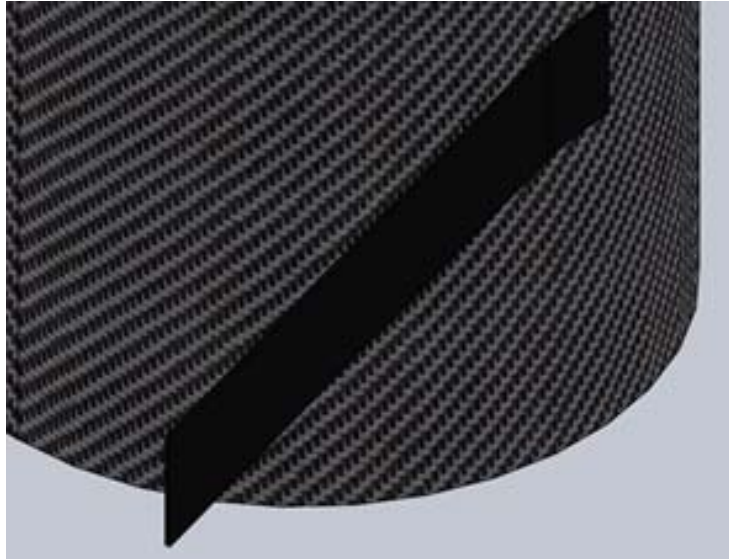
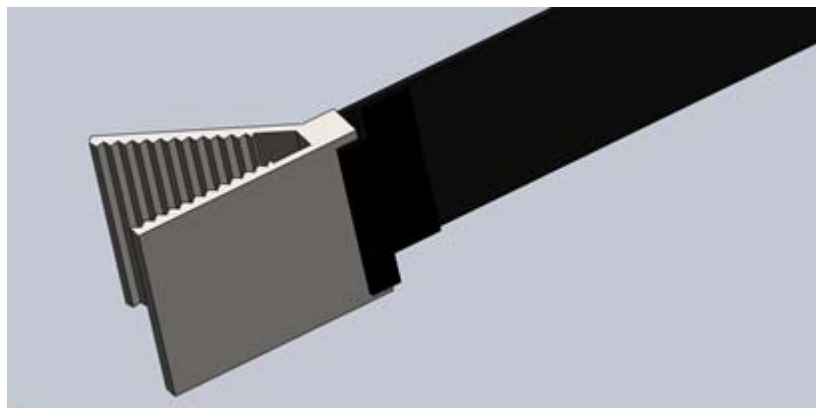


Figure 5.9

*Straps*

### 5.2.8. Metallic hookings

In the end of the straps there are two steel hookings to fix the cot to the belt of the adult. These metallic hookings are jagged in their interior to provide an ideal grasp of the device to the adult's belt since by means of the teeth of the interior it is impossible that the device can move.





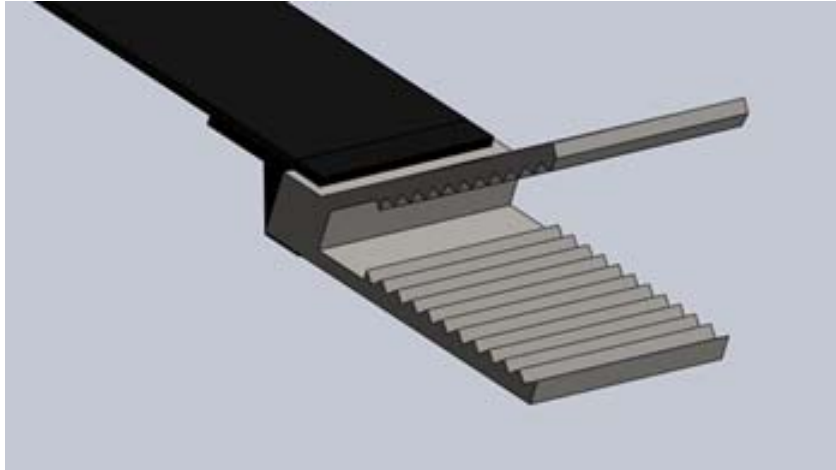


Figure 5.10

*Details of the metallic hookings*

These hookings are made of steel. The characteristics of this metal are not very important in what to resistance is referred for so that any type of steel can be used for their manufacture.

### **5.2.9. Interior hooking**

The last part of the device is an interior hooking in order that the infant travels inside the cot holded without the risk of going out of the cot.

This hooking would have on the one hand a female part and on the other a male part for the anchorage and it is sewed to the base of the cot. It would be made of steel and the female would be covered with plastic with a button to give up the anchorage. This device is exactly the same as the one used in the helmets of motorbikes for example.

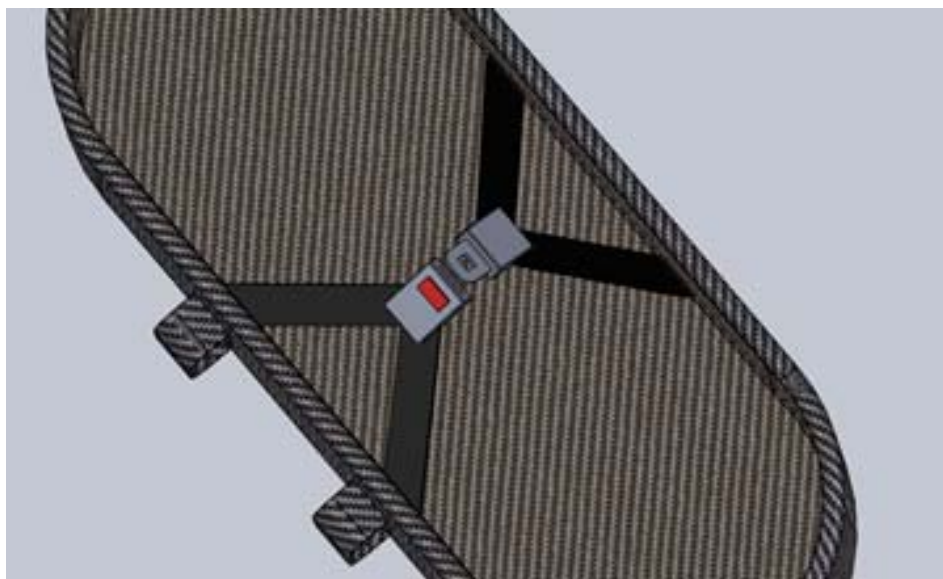


Figure 5.11

*Interior hooking*

The straps of the hooking are made of synthetic fiber as the lateral straps of the cot. It is possible to modify the length of the above mentioned straps for what it is possible to adapt the interior hooking to any size. This is very important because by this way it is guaranteed the safety of all the infants who travel in the new restraint device.

### 5.3. ANALYSIS

To verify the efficiency of the restraint device some standard tests are realized according to the specific regulation as it has been explained in the section 3.6 of this report. A frontal and a side impact test are done to check if the safety device is good enough to provide the suitable levels of safety. The first one is realized at a speed of 64 km/h and consists of striking a car against a deformable barrier that simulates another vehicle and the second one the vehicle is beaten by a deformable aluminum block at a speed of 50km/h.

Obviously I have not got the sufficient means to realize this analysis to the device. Instead of that it has been simulated an emergency stop with a car to prove the efficiency of the restraint device designed.

This test consisted on stopping the car from 50 km/h to 0 km/h and calculates the G forces that the infant would suffer. To calculate the G force it is necessary to know the variation of the speed and the time of stopped as the deceleration is defined by the next equation:

$$a = \frac{\Delta v}{t}$$

**Equation 5.1**

Where  $\Delta v$  corresponds to the variation of the speed in m/s and  $t$  to the time of stopped in seconds.

In this case the values are 13.88 m/s and 1.35 seconds respectively. Then the deceleration can be calculated:

$$a = \frac{\Delta v}{t} = \frac{13.88}{1.35} = 10.28 \text{ m/s}^2$$

Now to calculate the value of the G force it is necessary to divide this value between the value of the gravitational force, which is  $9.81 \text{ m/s}^2$ . The value of the G force that is suffered by the infant in this test is **1.05 G**.

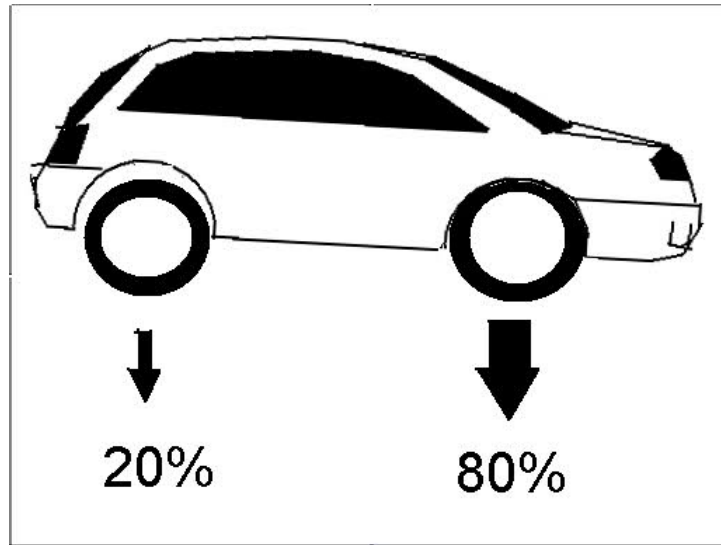


Figure 5.12

*Distribution of forces during a stopped*

We note that the value of this force is much smaller than the force that can be suffered in an air emergency that is between 7 and 9G forces.

During the accomplishment of this test two videos were recorded to be able to compare visually the different behavior of the infant with the two-point security belt used nowadays by the airlines and the new restraint device. It was clearly observed that there was risk of injury in the first cases since the force of stopped stimulated the body and the head of the baby ahead existing risks of injuries both in the neck and in the abdomen or vertebral column and how it was reduced with the new device since the infant travels inside the cot hooked with the interior hooking with less range of motion.

It should be remembered that these tests had been realized with forces of 1.05G so in an air emergency in which there can manage to be suffered forces of 7 or 9G the consequences for the infant can be fatal.

## 5.4. MANUFACTURING OF THE RESTRAINT DEVICE

For the accomplishment of the test and to have a better idea of the restraint device this one was manufactured making the fabrics and other parts of the design using a sewing machine yielded by Glyndwr University. In this section it is going to be explained the stages realized to make this device.



Figure 5.13

*Restraint device*

The first step to manufacture the device is to create the base of the cot. For it two caps of fabric are needed with the shape of ellipse of 80 centimetres of length and 34 centimetres of width. The ends of these pieces of fabric are rounded according to a semi circumference of 17 centimetres of radio. By this form the base remains oversized in order that sufficient fabric stays to sew the seam with facility having 2 centimetres extra around the whole base as it is shown in the picture.

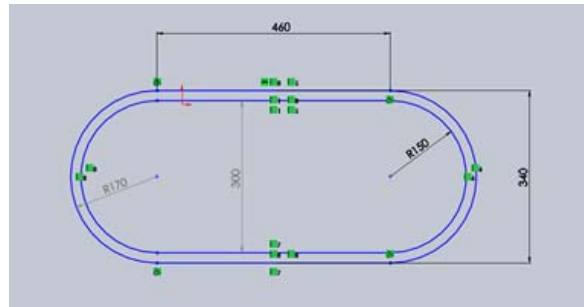


Figure 5.14

*Dimensions of the base*

Before sewing the whole perimeter of the base of the cot it is necessary to introduce the filling material between both caps to make the base quilted and comfortable for the infant. Then finish sewing the rest of the perimeter of the base. Finally the interior hooking can be sewed to the base of the cot.



Figure 5.15

*Detail of the interior hooking*

Once the base of the cot is ready the next step is the walls. For that it is important to distinguish between the interior and the exterior walls. For the exterior walls it is needed two pieces of fabric of measures 97 centimetres of length and 32 centimetres of width whereas for the exteriors the measures are 100 centimetres of length and 40 centimetres of width. The fact that there are needed two pieces of every

type of wall it is because each of them includes the half of the perimeter of the base. As in case of the base these measures are oversized.

In the top face of the base, on which the baby travels, there are sewed both pieces of the interior walls and once sewed both, join them by sewing at a height of the exterior edge of the base. In the other face the exterior walls are sewed by the same way. Once they are sewed they are turning around so that the seams remain hidden obtaining a better ended of the design.

Sewing the handles and the back loops to the exterior wall is advisable to facilitate the later work. To manufacture the handles it is necessary two strips of fabric of 44 centimetres of length and 8 centimetres of width. Then they are doubled for the half so that we have a strip of 4 centimetres of width and are sewed leaving 5 centimetres free in each side. Once this step is finished the handles are turning around in order that the seams remain hidden.



Figure 5.16

*Back loops and handles of the cot*

As soon as the walls are sewed, they are filled equally as the base. At the moment to sew the top part of the same ones, the exterior wall is doubled inside of the cot in order that a free space stays in the top edge. This one is the space where it will be put the elastic wire.



Finally the elastic wire is inserted in that space to provide the form to the contour of the cot. This elastic wire is inserted in the wing of the cot as it exists a hole in the union of the two parts of the walls. This is shown in the next picture.



Figure 5.17

*Elastic wire on the top edge of the cot*

As soon as the cot is finished, the lateral straps are added to the same one. These are sewed on the seam of union of both pieces of the exterior walls to guarantee that it could not break. Finally the metallic hookings are added in the end of the straps.



Figure 5.18

*Lateral straps and metallic hooking*

## 6. CONCLUSIONS



It exists studies which affirm that the current safety belt used onboard commercial transport aircraft, a two-point security belt, does not turn out to be sufficiently safe. And not only that but also it has been demonstrated that this type of belt can cause serious injuries of column or abdomen to adults. In case of infants these injuries can be major, managing to cause even the death. For these reasons, the aim of this project was to develop a new device to increase the security of infants.

The design of the device had to bear in mind the fulfillment of the air regulation referred to safety. This regulation is developed by the different aviation agencies, such as the European Aviation Safety Agency (EASA) in Europe, the Federal Aviation Agency (FAA) which belongs to USA, the Civil Aviation Authority (CAA) in UK, and must be followed by all the airlines.

Apart from that it was important to know all the emergency protocols that exist about evacuation of the plane in case of emergency to design the device adequately.

As far as the materials and components of the restraint device are concerned, it must be adapted to the regulations in terms of fireproof materials. As all the rest of materials that compose the cockpit of aircraft, they must be fireproof materials and expire with the necessary certifications of each country or aviation agency.

Besides adapting to the regulation, the new device must support all the efforts caused by turbulence, moderated or severe ones, and of other emergencies that can happen onboard aircraft as for example an emergency landing.

It exists some tests to prove the efficiency and the safety level that offer the different types of restraint devices. During an accident or emergency the passengers of the plane can manage to suffer forces of between 7 and 9G. To verify the efficiency of the new device it was realized a test that was consisting of one stopped of emergency from a speed of 50 km/h up to 0 km/h in which the infant was suffering forces of 1.05G.

This test was realized with the current system of safety used by the airlines, the two-point security belt, and with the new restraint device and in it it was possible to observe that the risk of suffering injuries of column, abdomen or neck of the infant were reduced drastically.

To summarize it is possible to say that with this new design of restraint device the safety of infants traveling by plane is increased as it has been demonstrated in the tests so that the initial aims of this project have been fulfilled.

To conclude, I want to say that as far as the improvements in the security of infants developed with this idea are concerned, I, Carlos Eder, save the intellectual property of the design of this restraint device in order to avoid plagiarisms in future designs.

## **7. RECOMMENDATIONS**

First of all I would like to remark that this new restraint device has been designed for infants of age between 0 and 1 year old.

An infant is defined as a person whose age is between 0 and 2 years of age. In agreement with the dimensions of the new designed device, this one is adapted for infants of until a year of age. For a future development of safety devices for infants it might say since recommendation that it would be a good idea to develop a new restraint device for infants of up to two years. Another possible solution might be to modify this device that has been explained here and adapt it to infants of all the ages.

Finally it is important to mention that any study and improvement in what to the safety of the passengers of the aircraft is referred has a great importance to avoid possible misfortunes in the future.

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